INNOVATIVE TECHNOLOGY

Summary Report

DOE/EM-0546

XRF Analysis of PCBs and Inorganics

Deactivation and Decommissioning Focus Area

Prepared for

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INNOVATIVE TECHNOLOGY
Summary Report

XRF Analysis of PCBs and Inorganics

OST/TMS ID 2398

Deactivation and Decommissioning
Focus Area

Demonstrated at
Idaho National Engineering and Environmental Laboratory
Idaho Falls, Idaho

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine whether a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under "Publications."

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SECTION 1
SUMMARY

Technology Summary

The United States Department of Energy (DOE) continually seeks safer and more cost-effective technologies for the decontamination and decommissioning (D&D) of nuclear facilities. To this end, the Deactivation and Decommissioning Focus Area (DDFA) of the DOE's Office of Science and Technology sponsors large-scale demonstration and deployment projects (LSDDPs). At these LSDDPs, developers and vendors of improved or innovative technologies showcase products that are potentially beneficial to the DOE's projects as well as others in the D&D community. Benefits sought include decreased health and safety risks to personnel and the environment, increased productivity, and decreased cost of operation.

The Idaho National Engineering and Environmental Laboratory (INEEL) LSDDP generated a list of need statements defining specific needs or problems where improved technologies could be incorporated into ongoing D&D tasks. Advances in characterization technologies are continuously being sought to decrease the cost of sampling and increase the speed of obtaining results. Currently it can take as long as 90 days to receive results from contract laboratories on soil, liquid, and paint samples. The cost of analysis at these contract laboratories often exceeds $1000 per sample.

This demonstration investigated the feasibility of using the SPECTRO XEPOS X-ray Fluorescence (XRF) Analyzer (innovative technology) to measure Polychlorinated biphenyls (PCBs) and RCRA metals in paint and soil where contract laboratories (baseline technology) are currently being used on D&D sampling activities. Benefits expected from using the innovative technology include:

- Significant decrease in time to receive results on environmental samples
- Reduction in worker exposure due to less sample media required
- Decrease in cost associated with sample collection, preparation, and analysis
- Equivalent data quality to laboratory analysis

This report compares the cost and performance of the baseline laboratory analysis to the cost and performance of the SPECTRO XEPOS Analyzer.

Baseline Technology

Many facilities at the INEEL and other DOE complexes have become obsolete and are being demolished or dismantled. Prior to performing any decontamination or dismantlement work, D&D projects characterize the site. The results of the characterization are used to plan the D&D work at that site. It is therefore important that characterization work be performed quickly and results be provided to the project managers in a timely manner so that work objectives can be outlined and planned such that milestones are met. Currently, D&D project managers rely on contract laboratories to provide results to environmental sampling. Typically, at least two samplers collect samples of soil, water, paint, or other media to be sent to the contract lab. The contract lab specifies the amount of sample needed in order to provide quantifiable, reproducible results. The amount of sample required typically ranges from 10 to 500 grams per sample and generally two (duplicate) samples are sent each time.

Generally, the project manager requests analysis of Resource Conservation and Recovery Act (RCRA) metals, volatile organics, and PCBs from contract laboratories. In the case of paint sample collection, the samplers use hand-held tools such as chisels or putty knives to strip paint away from the surface. This can be a time-consuming task when large volumes of sample material are required. Once the samples have been collected, samplers follow specified protocols to ensure that the samples remain intact and representative of the media present in the original location. Holding times are specified for each type of analysis and the samples must be stored at 4 °C during the period between collection and analysis at the contract lab. Once the sample has been taken, it may take as long as 90 days for the project manager to receive the results.

Figure 1. Collection of Paint Samples

Innovative Technology

Engineers at the INEEL have identified an instrument that can provide results quickly to the project managers so that D&D projects can be planned in a much shorter time. The innovative technology, an X-ray fluorescence spectrometer, uses polarized radiation to detect elements ranging from sodium to uranium. Before analysis, sample material must be ground up and mixed uniformly to ensure accurate results. However, there is no digestion process required, which eliminates the possibility of procedural errors associated with sample preparation. A technician can easily be trained to grind and mix the sample material in minutes, while digestion procedures like those used at contract labs require much more training to ensure the samples are properly prepared.

In this demonstration both grinding and mixing were achieved using a Chemplex SPECTROMill shown in Figure 2. Other grinding and mixing devices are available on the market, but the INEEL already owned this piece of equipment. Paint and soil samples are placed in a stainless steel cup and ground into a powder and mixed thoroughly. A binding agent SPECTROBlend was added to the powder. The powder is then placed in a press to form a pellet. The press used in this demonstration was a Chemplex SPECTROPress shown below (Figure 3). The pellets are then placed on the SPECTRO XEPOS for analysis (Figure 4).

Figure 2. Chemplex SPECTROMill

Figure 3. Chemplex SPECTROPress

With the sample now formed into a small pellet, the SPECTRO XEPOS is used to analyze the sample. The SPECTRO XEPOS XRF Analyzer (Figure 5) uses polarized radiation in x-ray fluorescence (XRF) spectrometry to detect elements from sodium to uranium. At the INEEL, the SPECTRO XEPOS was also used to detect the possible presence PCBs in various media (soil, paint, PPE, liquid, and oils) by measuring the total chlorine concentration. The sample analysis can be completed the same day the samples are collected, providing a near real time output for the user. The SPECTRO XEPOS can measure the concentration of total chlorine (organic chlorine and chloride salts) in a sample, but cannot differentiate between the two chlorine species. The operator must have some process knowledge of the sample or compare against known background levels, and verify the results with laboratory analysis. The user can determine that PCBs are not present if chlorine is not found in the sample, since chlorine is an elemental component of PCB. The XEPOS provides simultaneous determination of the elements present in a single measurement which varies from 100 to 500 seconds in length depending upon quality objectives. The results can be printed or saved as an electronic file for later use. Predefined methods for measurement, spectral deconvolution, calibration and data output reduce the need to create new methods for each analysis. The system can be set up with multiple internal standards that are matrix matched for various media such as soils, water, coatings, biological materials etc.

Figure 4. Samples Pressed into Pellets for Analysis

Figure 5. SPECTRO XEPOS

Demonstration Summary

The innovative technology was demonstrated in November 1999. Paint and soil samples were collected in June, July, August, and September. Lori Lopez and Roger Mocli, D&D environmental samplers at the INEEL, collected the samples. Paint samples were collected from the Test Reactor Area (TRA) 660 canal, the delay tanks at the Engineering Test Reactor (ETR) area, and at Intec 709. Soil samples were collected at the Security Training Facility (STF). The samples were stored at 4° C at the sampling laboratory at Central Facility (CF) 625. For the purpose of the baseline, the samples were uniformly mixed, separated into appropriate containers, and shipped to the contract lab for analysis. Table 1 shows the sample dates, shipping dates, and the dates when the results were returned to the INEEL from the contract lab.

Table 1. Sample Collection Information

Sample ID	Sample Date	Shipping Date	Date Received Data
TRA Delay Tanks (paint)	9-20-99	9-20-99	10-28-99
INTEC 709 (paint)	6-14-99	6-14-99	7-22-99
TRA 660 (paint)	7-13-99	7-13-99	8-16-99
WERF Incinerator (PPE)	7-15-99	7-15-99	8-25-99

The samples were prepared by using the SPECTROMill to grind and uniformly mix the sample material. This step is especially important for coatings that are quite thick. X-ray fluorescence spectrometers generally only measure the top surface of the sample, so it is important to grind and mix the sample so that you are getting a uniform reading that is representative of the entire sample, not just the surface. A binding agent (SpectoBlend) was added to the sample and mixed thoroughly so that the sample could be pressed into a tight pellet and would not crumple into pieces. Four grams of sample were formed into a small thin pellet.

On November 1, the SPECTRO XEPOS arrived at the INEEL and was transported to the Central Facility Area building 625, where it was inspected. On November 15, a representative from SPECTRO arrived and set up the instrument and provided training. On November 19, the samples that were previously collected were analyzed using the SPECTRO XEPOS.

Contacts

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Web Site

The INEEL LSDDP Internet web site address is http://id.inel.gov/lsddp

Licensing

No licensing activities were required to support this demonstration.

Permitting

No permitting activities were required to support this demonstration.

Other

All published innovative Technology Summary Reports are available on the OST Web site at http://em-50.em.doe.gov under “Publications.” The Technology Management System, also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST Reference Number for the SPECTRO XEPOS XRF Spectrometer is OST 2398.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

Demonstration Goals and Objectives

The overall purpose of this demonstration was to assess the benefits that may be derived from using the SPECTRO XEPOS over the baseline method, sending the samples to the laboratory. The demonstration collected operational data so that a legitimate comparison could be made between the innovative technology and the baseline technology in the following areas:

- Safety
- Productivity rates
- Ease of use
- Benefits/Limitations
- Cost.

Description of the Technology

The SPECTRO XEPOS, the innovative technology, is an X-ray fluorescence spectrometer which uses polarized radiation to detect elements ranging from sodium to uranium. Prior to analysis, the sample material must be ground up and mixed uniformly to ensure accurate results. However, there is no digestion process required, which minimizes the possibility of procedural errors associated with sample preparation. A technician can easily be trained to grind and mix the sample material in minutes, while digestion procedures like those used at contract labs require much more training to ensure the samples are properly prepared.

Specific advantages of the SPECTRO XEPOS include the following:

- A much faster turnaround on the sample results.
- Only 4 grams of sample material is needed for the analysis as opposed to hundreds of grams required by contract laboratories.
- The SPECTRO XEPOS does not require samples to be digested or otherwise prepared before analysis. Because of this, the samplers can easily perform the analysis without expecting problems associated with procedures or methods being compromised.
- Because less sample material is required, samplers are exposed to hazards for a much shorter duration.
- The new technology may eventually eliminate the need to ship samples offsite.
- Faster turn-around times result in D&D schedules being reduced, resulting in cost savings.

System Operation

Table 2 summarizes the operational parameters and conditions of the SPECTRO XEPOS demonstration.

Table 2. Operational parameters and conditions of the SPECTRO XEPOS demonstration

Working Conditions	
Work area location	CFA 625, room 120
Work area access	Access controlled by keycard access
Work area description	The work area is the sample lab for the D&D samplers.
Work area hazards	
Equipment configuration	The equipment is maintained and used in CF 625 room 120. It is set up on the counter-space available in the laboratory.
Labor, Support Personnel, Special Skills, Training	
Work crew Sampling	Minimum work crew: • 2 samplers
Analysis	• 1 sampler
Labor, Support Personnel, Special Skills, Training (cont'd)	
Additional support personnel	• 1 data collector • 1 health and safety observer (periodic) • 1 test engineer
Special skills/training	Special training was required to operate the SPECTRO XEPOS. The vendor supplied 3 days of training with the purchase of the equipment.
Waste Management	
Primary waste generated	No primary wastes generated
Secondary waste generated	Disposable personal protective equipment
Waste containment and disposal	All secondary wastes were collected and packaged for disposal with the D&D project waste.
Equipment Specifications and Operational Parameters	
Technology design purpose	Analytical equipment was needed to perform accurate onsite analysis of environmental samples.
Portability	The SPECTRO XEPOS will be kept and maintained in CF 625 room 120.
Materials Used	
Work area preparation	Preparation was required to ensure that the instrument was properly registered and set up according to Management Control Procedure (MCP)-138, Radiation Generating Devices.
Personal protective equipment (the equipment needed for this demonstration was specific to the sampling tasks involved and could vary greatly from job to job.	• Cotton glove liners • Tyvex coveralls • Respirators • Pair of rubber gloves • Shoe covers • Steel toe shoes • Hard hats • Safety glasses
Utilities/Energy Requirements	
Power, fuel, etc.	220 volt AC power required

SECTION 3
PERFORMANCE

Demonstration Plan

Problem Addressed

D&D project managers are required to characterize the conditions present at each D&D task to properly plan and estimate schedules and budgets for the project. For instance, paint and soil must be characterized to determine whether it must be removed, and what parameters will be required for its disposal. At the INEEL, environmental samples are sent to offsite contract laboratories for analysis. This process involves the collections of samples ranging from 100-500 grams and may take in excess of 90 days to receive results. There is a need for a method to detect PCBs and RCRA metals quickly. Minimizing the volume of sample that must be collected is also a concern. Therefore, the new technology should offer quick results while minimizing the volume of material that needs to be collected. Currently the INEEL also uses small test kits for some contaminants. These test kits use reagents which when added to the sample result in a mixed hazardous waste that must be disposed as such.

The purpose of this demonstration is to compare the performance of the innovative technology, the SPECTRO XEPOS, to the baseline technology, contract laboratories. Soil and paint samples were collected from various locations at the INEEL for analysis.

Demonstration site description

The INEEL site occupies 569,135 acres (889 square miles) in southeast Idaho. The site consists of several primary facility areas situated on an expanse of otherwise undeveloped, high-desert terrain. Buildings and structures at the INEEL are clustered within these primary facility areas, which are typically less than a few square miles in size and separated from each other by miles of primarily undeveloped land.

There are many buildings at these primary facilities that have become obsolete and are being removed or renovated for future use by the INEEL D&D group. As part of this process, D&D must first perform a variety of environmental sampling to determine if the site has been contaminated and how to dispose of various building materials. For this demonstration, samples were collected from TRA, STF, and Idaho Nuclear Technology and Engineering Center (INTEC) during scheduled D&D characterization projects. The samples were stored at CF 625 room 120 at 4° C. Samples were shipped to an offsite contract laboratory for analysis and a portion of the sample was retained for analysis with the innovative technology.

Major objectives of the demonstration

The major objective of this demonstration was to evaluate the SPECTRO XEPOS XRF Spectrometer and compare it to the baseline method of sampling in the following areas:

- Cost effectiveness (based on speed of result acquisition and sampling)
- Safety
- Ease of use
- Benefits/Limitations.

Major elements of the demonstration

Both the baseline technology and the innovative technology analyzed the same samples. The intent of the demonstration was to gather information helpful in deciding if the innovative technology could provide results equal in quality to the contract laboratories but with a faster turn-around or process time. This demonstration tested soil and paint samples from a variety of locations. Common elements of the demonstration included:

- Sample collection time
- Sample preparation time
- Number of workers required
- Safety
- Worker comments
- Cost
- Advantages/Disadvantages.

Results

Both technologies were evaluated using splits from the same samples. Every attempt was made to allow work to proceed under normal conditions with no bias. All parties involved in the demonstration were requested to perform the work normally with no special emphasis on speed or efficiency. Samples were collected from July to September and shipped to the contract laboratory immediately following collection. Samples from the same areas were analyzed on November 16, 1999 when the instrument arrived at the INEEL.

During the comparison, the same samplers were used throughout the project to collect, prepare, ship, and/or analyze the samples. A total of 18 samples were analyzed using the innovative technology. A video was taken of the sample collection. Video was also taken at the time the innovative technology was demonstrated at the INEEL. No video was collected from the contract laboratory. The performance of the two technologies is compared in Table 3.

Table 3. Performance comparison between the innovative and the baseline technology.

Performance Factor	Baseline Technology Sample Analysis at a Contract Laboratory	Innovative Technology Sample Analysis using the SPECTRO XEPOS
Personnel/equipment/ time required to collect samples from TRA Filter Pits	Personnel: • 2 samplers • 1 Radiological Control Technician (RCT) Time: • 15 minutes to move the scaffold from the staging area into the work zone	Personnel: • 2 samplers • 1 RCT Time: • 15 minutes to move the scaffold from the staging area into the work zone
Personnel/equipment/ time collect paint samples at INTEC 709	Personnel: • 2 Samplers • 1 RCT (provide periodic inspection) Equipment: • Chisel and Hammer Time: • 3 hours (1000 grams)	Personnel: • 2 Samplers • 1 RCT (provide periodic inspection) Equipment: • Chisel and Hammer Time: • 10 minutes (30 grams)

Performance Factor	Baseline Technology Sample Analysis at a Contract Laboratory	Innovative Technology Sample Analysis using the SPECTRO XEPOS
Personnel/equipment/ time required collect soil samples at STF facility	Personnel: • 2 Samplers • 1 RCT (provide periodic inspection) Equipment: • Shovel Time: • 15 minutes (200 grams)	Personnel: • 2 Samplers • 1 RCT (provide periodic inspection) Equipment: • Shovel Time: • 5 minutes (30 grams)
Personnel/equipment/ time required collect paint samples at TRA ARMF/CRMF Canal	Personnel: • 2 samplers • 1 RCT Equipment: • chisel and hammer Time: • 2 hours (200 grams)	Personnel: • 2 samplers • 1 RCT Equipment: • chisel and hammer Time: • 9 minutes (15 grams)
Personnel/equipment/ time required collect paint samples at TRA delay tanks	Personnel: • 2 samplers • 1 RCT • 1 Yardman Equipment: • chisel and hammer Time: • 1.5 hours (200 grams)	Personnel: • 2 samplers • 1 RCT • 1 Yardman Equipment: • chisel and hammer Time: • 5 minutes (15 grams)
Time required to prepare the samples for shipment or analysis	Personnel: • 2 samplers Equipment • Sample mixer	Personnel: • 2 samplers Equipment • Sample mixer
Personal Protection Equipment (PPE) requirements	Both technologies require the same number of workers to wear the same level of PPE to complete the job.	
Superior capability	• EPA approved method of analysis.	• Less sample material required resulting in fewer labor hours and less time spent in potentially hazardous environments. • Cost savings over laboratory analysis. • Much faster turn around time for receiving sample results. • Effective at analyzing a broad variety of sample materials (including paint, liquid, oils, soil, concrete, and PPE.

TRA Filter Pits

Paint samples were collected from support structures of the delay tanks at TRA. The delay tanks, a component of the Engineering Test Reactor (ETR) facility at TRA, are located about 40 ft below ground level. To collect paint material, samplers removed manhole covers and climbed down ladders into the delay tank rooms. Because of the difficulty in entering and exiting this area, it was designated as a confined space. A person was stationed outside the manhole entrance to ensure the safety of the workers. Samples were collected from the support structure of the delay tanks as shown in Figure 6.

Figure 6. Collection of Paint Samples at TRA Delay Tanks.

Paint samples were accumulated by scraping paint into collection pans as seen above. Once enough material was collected, it was mixed uniformly. It took 90 minutes for 3 samplers to collect about 700 grams of paint material for analysis. The laboratory required two 70-gm samples for metals, two 90 gm samples for volatiles, and two 150 gram samples for PCBs. Three 5-gram samples were retained for analysis on the SPECTRO XEPOS. The samples analyzed on the SPECTRO XEPOS required 17 minutes of preparation time and approximately 20 minutes for analysis. The samples shipped to the laboratory required 20 minutes to prepare for shipment, required 37 days for shipment of samples, analysis of samples, and mailing of results back to the laboratory. Another 2 weeks was required for verification of results and distribution of results to the project manager.

The test engineer gathered all of the data and the information and generated Figure 7, which shows that the SPECTRO XEPOS compared very well with the laboratory results.

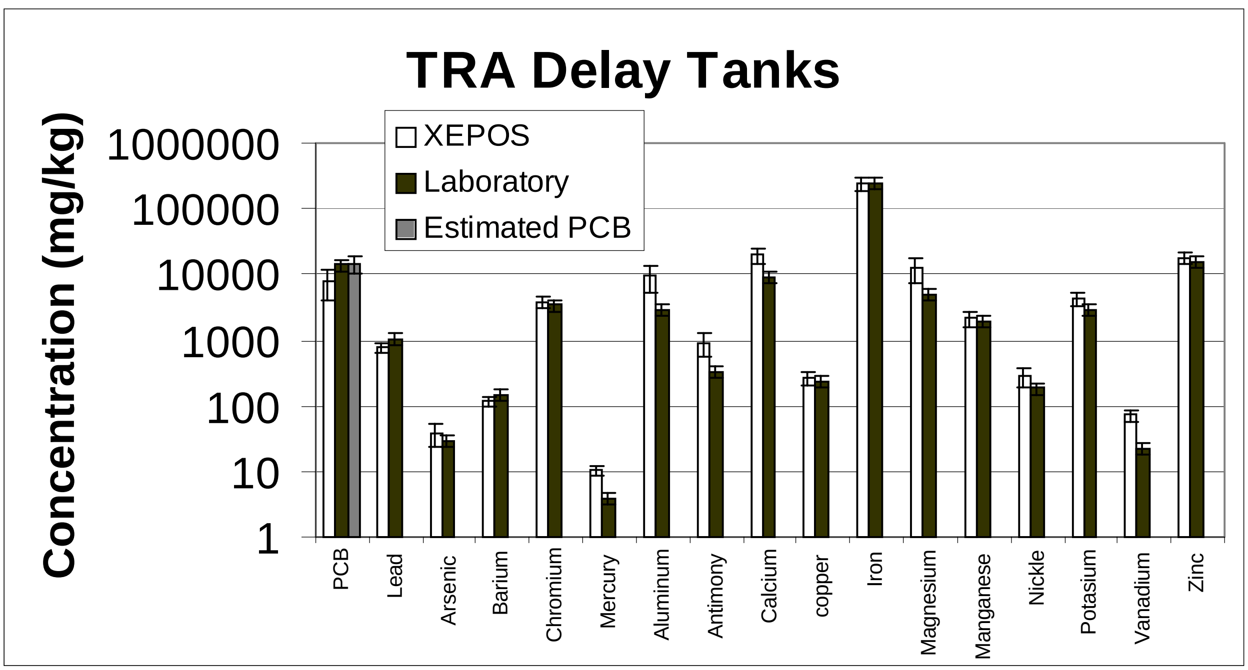

Figure 7. TRA Delay Tank Paint Analysis.

The error bars on the SPECTRO XEPOS analysis were based on one standard deviation from the analysis of 3 samples. The error bars associated with the laboratory analysis were calculated as a 20% error on one sample. In this case, the greatest error occurred on the analysis of the mercury and vanadium.

There are three bars shown for the analysis of PCB in this sample. These three bars represent, 1st the concentration of total chlorine in the sample, 2nd the laboratory determined concentration of PCB in the sample, and third the estimated concentration of PCB determined from the chlorine concentration found by the SPECTRO XEPOS. The calculated PCB concentrations were determined by using the measured total chlorine concentration from the XEPOS (which account for the organic chlorine and the chlorides, although it was believed that no chlorides existed in the paint) and dividing by the organic chlorine content (54%) of the specific PCB Araclor (Arachlor 1254) as determined from the laboratory. The laboratory results provides a breakdown of the different Arachlors that may be present in the sample. In this case, the only PCB Arachlor present was 1254. Using this calculation, it can be seen that the estimated PCB concentration and the laboratory determined concentration match almost identically.

INEEL Nuclear Technology and Engineering Center (INTEC)

INTEC 709 is a pump station building (Figure 8). A doorway accesses an underground pump room. A sump room with ladder access is located directly below the pump room. All equipment has been removed from CPP 709, leaving the two rooms vacated. The pumping room has painted walls with low levels of possible radionuclide contamination. The lower sump room has an epoxy coating, which also has possible radionuclide contamination. The paint in both the pump room and the coating from the sump room were collected and analyzed for metals, PCBs, volatile organic compounds (VOCs), and radionuclides.

In each room, three 4-gram samples were prepared to be analyzed on the SPECTRO XEPOS. Samples were also sent to a contract laboratory, where they were analyzed for PCBs and inorganic analysis. The inorganic analysis is used to determine total element concentrations for the sample analyzed.

Figure 8. INTEC 709 Pumping Station.

The results for the PCB analysis in both the laboratory data and in using the SPECTRO XEPOS show that the PCB levels in the paint exceeded the allowable level of 50-parts per million by weight (ppmw) (Figure 9). There was a significant difference between the PCB concentrations using the innovative and baseline technologies, but it may be due to the presence of other chlorinated compounds. The innovative and baseline technologies did compare well for the inorganic analysis as can be seen from Figure 9. The exceptions to this are that the SPECTRO detected beryllium and thallium while the laboratory did not. In addition, selenium, silver, antimony, and arsenic were not detected by either the baseline or innovative technology.

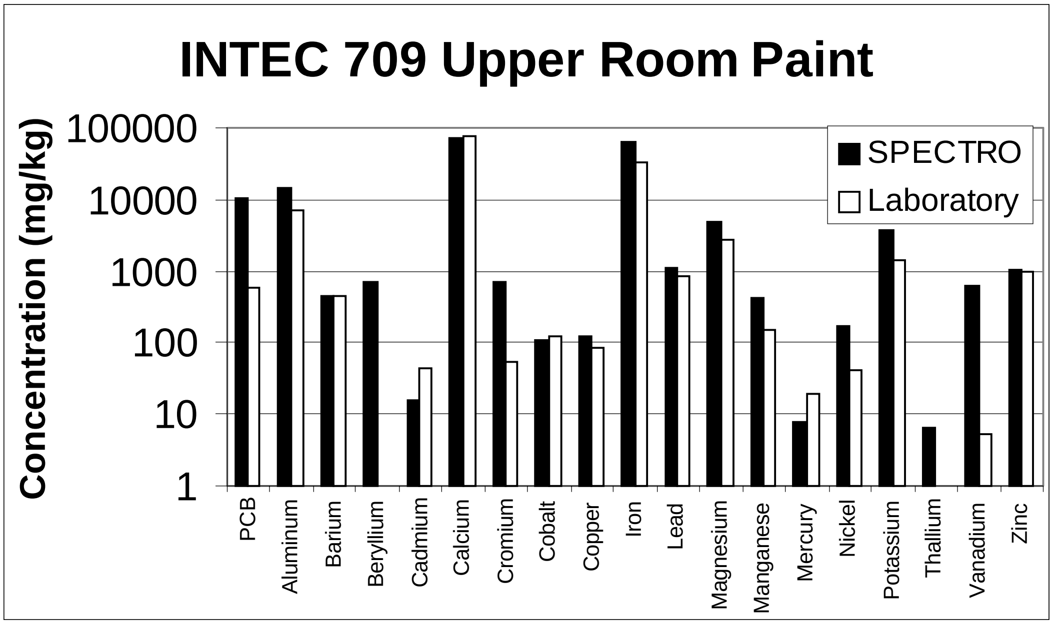

Figure 9. Sample results from the INTEC 709 upper room paint.

The PCB analysis results of the coating found in the sump room of INTEC 709 did not correlate as well as the paint analysis for the upper room shown in Figure 9. The uncertainty in the data could not be explained without further analysis being performed. Figure 10 shows that the SPECTRO XEPOS found levels of total chlorine to be in excess of 1,000 ppmw, while the PCB concentration was less that 50-ppmw as determined by the laboratory. In general, the inorganic analysis of the sump room coating compared well between the innovative and baseline technologies. Again, beryllium and thallium was detected using the innovative technology, but not with the base line technology. Antimony, cadmium, selenium, and silver were not detected using either technology, and were not presented in Figure 10.

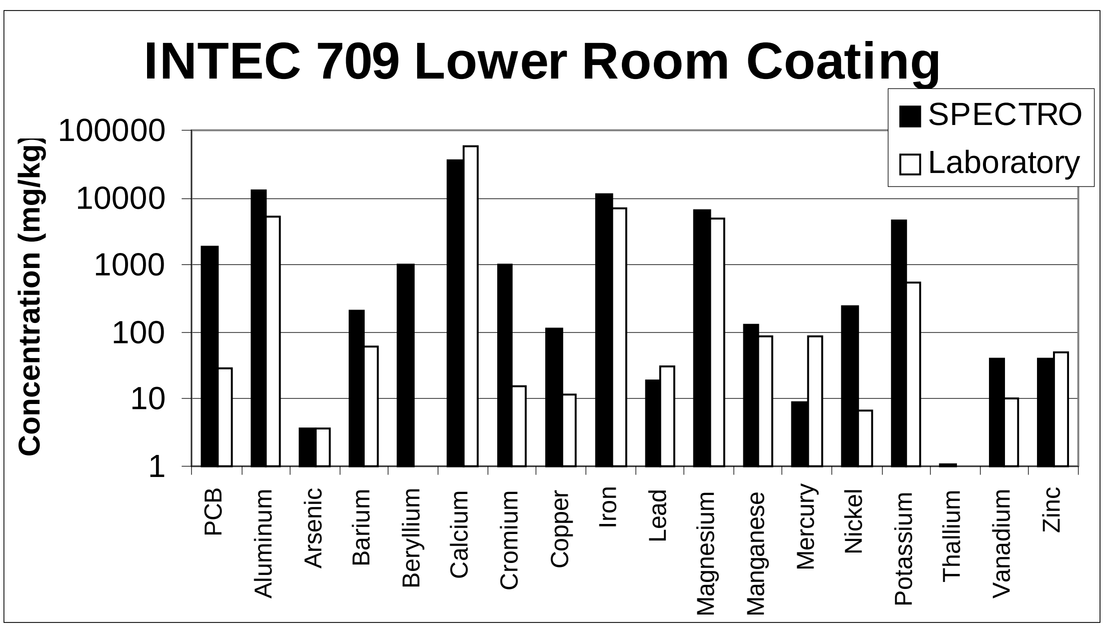

Figure 10. INTEC 709 Lower Room Coating

WERF Incinerator

The WERF incinerator operators are required to provide the State of Idaho with the total chlorine concentration of the waste being incinerated in the Incinerator. The waste being incinerated is made up primarily of PPE (gloves, tyvex suits, etc.) and various forms of plastic pipe or tubing. A sample of glove material and tubing was analyzed using the SPECTRO XEPOS and compared to laboratory data. Based on the results of this comparison, the WERF operators are considering the acquisition of an XRF analyzer similar to the SPECTRO XEPOS to use for chlorine analysis of waste prior to incineration. The SPECTRO XEPOS results correlated well with the laboratory results even at these high concentrations (Figure 11). Note that it was difficult to fit the sample material into the sample position, especially when analyzing the tubing. Multiple measurements were not taken on these samples, therefore the error could not be determined.

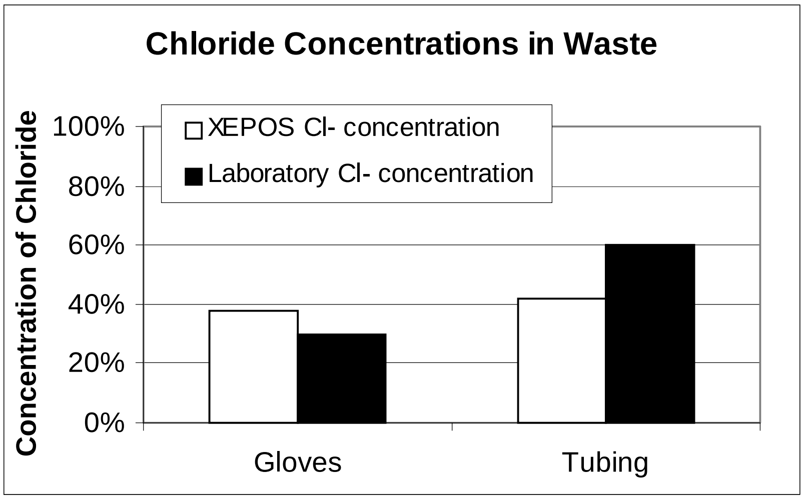

Figure 11. Incinerator Waste Characterization.

Hydraulic Oil

In order to excess a piece of equipment, the hydraulic oil in the equipment needed to be tested for metals and PCB. We used the SPECTRO XEPOS to measure for inorganics and for total chlorine as a screen to identify the possibility of PCBs. The results showed total chlorine to be below detection in the oil. Based on this, we determined that the equipment could be free released for excess. This was also confirmed by laboratory analysis, which showed no detectable PCBs.

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

Baseline technology

The baseline technology for this demonstration was to collect samples and ship them to a contract laboratory for analysis.

Other competing technologies

There are a variety of X-ray fluorescent (XRF) spectrometers and other analytical instruments available for the purpose of analyzing environmental samples and in particular PCBs. The advantage of XRF is that it eliminates the need for time-consuming, difficult digestion procedures used to measure PCBs and inorganic contaminants, which is required with conventional analytical equipment. The x-rays can penetrate the original sample matrix to excite electrons in the sample. Additionally, the SPECTRO XEPOS has internal standards that come with the instrument that eliminate the need for calibrations associated with each type of matrix encountered. Additional standards can be added to the instrument's database as needed. Below are listed some of the technologies that were reviewed for the purpose of this demonstration.

Dexsil L2000

The Dexsil L2000 is a portable instrument that provides a fast, easy, accurate way of quantifying PCBs in both soil and transformer oil. It has a detection range from 2 to 2,000 ppmw. It uses a chloride-specific electrode to quantify the concentration of PCBs in a sample after the sample has been reacted with a reagent that removes all of the chloride from the organic molecule. The instrument converts the chloride reading into ppmw PCB and displays the result on the LCD readout.

The L2000 is sensitive to organic chloride from any source, not just PCBs, so if other chlorinated organic compounds are present, they will be detected as well. Inorganic chlorides such as road salt will not be detected by this method. It can be operated over a temperature range of 5°C to 45°C. The results achieved with the L2000 are unaffected by moisture up to 20%.

While this instrument provides quick accurate results for PCBs in soil and transformer oil, it did not advertise a capability to be able to detect PCBs in paints and coatings, which was of particular interest to the D&D samplers. The Dexsil L2000 produces a secondary liquid waste that must be disposed of. The need listed by the D&D workers required a technology that did not produce a secondary waste. The Dexsil L2000 claims to provide accurate results for PCBs, but does not provide analysis of other contaminants. The SPECTRO XEPOS is used as a screening tool for PCBs, but also provides quantifiable analysis of 50 inorganic contaminants as well.

Immunoassay for PCBs

Immunoassay is an analytical technique that takes advantage of the antibodies ability to selectively bind to the target of analysis extracted from an environmental sample. The antibody does not respond to dissimilar substances. The strength of the antibody bond is known as the affinity constant. Quantitation is performed by monitoring either for a color change either visually or with a photometer. The immunoassay methods are simple to use and easily portable. Methods have been developed for accurately measuring liquid and soil samples at least at preset concentrations.

Limitations of the immunoassay method include:

- Not appropriate if quantitative results are required,
- If multiple similar compounds are present, there is a risk of interference,
- Typically not used for solids such as PPE, tubing, or metals
- The test kits that were investigated had not been tested on paint chips

- Produce a secondary waste that must be disposed of.

Gas Chromatography (GC)

Gas chromatography is designed to resolve or separate a mixture of compounds in order to detect each compound separately. Separation occurs as the compounds present in a sample interact with a stationary phase compound coated on the inside of a column. The sample is transported by a carrier gas usually (nitrogen, helium, or hydrogen) through the GC column. Samples typically measured on a GC are gases. Liquid samples are also analyzed by injection into a heat vaporization chamber that transforms the liquid into a gas for analysis.

Because the GC measures only gas phase, solids such as soils must first go through an extraction or digestion process that concentrates the contaminants of concern in a liquid sample that can then be injected on the GC for analysis. The D&D workers at the INEEL were in need of a technology that did not generate a secondary waste and did not require much effort to prepare the sample for analysis.

The use of GC to analyze for PCBs in solid wastes such as PPE is also not practical. Extraction procedures for paint chips and epoxy coatings are also limited in applicability.

Technology Applicability

The innovative technology is fully developed and commercially available. Its advantage is derived from its ease of use and ability to provide data the same day the samples are collected. This advantage can save time and money across the DOE complex. It has potential to reduce costs for many D&D projects. The INEEL is currently investigating the possibility of eliminating the need for analysis at contract laboratories and replacing it with technologies such as this.

Patents/Commercialization/Sponsor

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SECTION 5
COST

Methodology

This section compares the sampling and characterization costs for the innovative technology with the cost of the baseline sampling and characterization method. In this demonstration, the cost to use the innovative technology is approximately 6% of the baseline technology cost. This cost analysis is based on observing sampling from four different test sites. The work consisted of mobilization of the crew and equipment to the sampling site, taking samples, packaging and sending the samples to the lab (baseline), or analyzing the samples with the SPECTRO XEPOS Analyzer (innovative).

The costs for the innovative and baseline technologies are derived from observed duration of the work activities that are recorded as the demonstration proceeds as well as the Test Engineer's judgement and experience. The amount of characterization work performed for the innovative technology differed from the baseline because of the different amount (grams) of sample size needed for analysis. The lab requires a sample size of at least 90 grams, as opposed to the SPECTRO XEPOS Analyzer, which only requires five grams. Thus, sampling times for the SPECTRO XEPOS Analyzer were much lower. In addition, the number of samples for the innovative technology varied from the baseline's amount (12 samples for the innovative and 28 samples for the baseline). This cost analysis assumes 28 samples were taken for both the innovative and the baseline technologies and uses the average production rate observed to compute the additional 16 samples for the innovative technology.

The number of persons involved in the demonstration work varied from three samplers to one sampler. However, during normal operations the standard number of samplers is two. Therefore, the sampling times for samples completed by more or less than two were normalized to represent two samplers. Both technologies require the same number of samplers. The only tasks that required additional personnel were the pre-job safety meeting and the sample analysis validation. Based on the judgement and experience of the test engineer, the pre-job safety meeting included an additional job supervisor, a skilled laborer, a radiation technologist, and an industrial hygienist. The sample analysis validation only requires the services of a chemist.

The equipment rates are based on the amortized purchase price and maintenance costs. The Baseline Technology equipment calculation is an allowance for small tools not covered by overhead or included in the labor rates. Small tools comprise a metal basin, scrapers, hammers, collection pans and sample containers. Ownership and operating costs for the SPECTRO XEPOS Analyzer and the Chemplex Press includes repairs, maintenance, source replacements, software upgrades, parts inspections, cleaning and preventive upkeep.

This cost analysis omits costs for activities that relate only to the demonstration. The time spent logging the data into the daily journals is an example of the type of demonstration-related activities that are omitted. The estimated costs include work delays and inefficiencies that are typical for real work situations. An example of work delays and inefficiencies observed for this demonstration is the 5-minute period between finishing the pre-job briefing and donning the PPE gear. These costs are identified in this cost analysis as productivity loss and consist of the accumulated duration of the delays and inefficiencies observed during the demonstration.

A method of mixing/grinding of the samples is a required part of the sample preparation process. The INEEL used the SPECTRO Mill to accomplishing the mixing/grinding need of the demonstration. This piece of equipment was already owned by the INEEL. There are numerous possibilities for grinders/mixers ranging from approximately $100 to several thousand dollars depending on the needs of the project. The cost of the SPECTRO Mill was not discussed in the ITSR because of the broad range of products that could be used. It should be noted, that a mixer/grinder is needed for sample preparation, and should be considered when purchasing a SPECTRO XRF.

Additional details of the basis of the cost analysis are described in Appendix B.

Cost Analysis

Costs to Purchase the Technology

The innovative technology equipment is available from the vendor with optional components. The purchase prices of the basic equipment and optional features used in the demonstration are shown in Table 4, and costs for the baseline are shown in Table 5. A leasing agreement can be obtained from Asoma Instruments for the SPECTRO XEPOS Analyzer. This agreement would be 10% of the non-discount purchase price ($75,000) per month. Purchase of the equipment is an option within the first four months, and 75% of the accrued leasing payments could be put towards the purchase price.

Table 4. Innovative Technology Acquisition Costs

Acquisition Option	Item Description	Cost
Equipment Purchase	SPECTRO XEPOS Analyzer	$63,072
Equipment Purchase	Chemplex Manual Press	$2,200
Equipment Purchase	Small Tools	$150

Note: The calibration costs for the Spectro Xepos Analyzer is included in the study's cost comparison between the innovative and baseline technologies.

Table 5. Baseline Technology Acquisition Costs

Acquisition Option	Item Description	Cost
Equipment Purchase	Small Tools	$150

The amortized cost of owning the equipment (amortization of the purchase price) and the cost for operation, maintenance, and calibration on a per-hour basis are summarized in Table 6.

Table 6. Ownership and Operating Costs

Equipment	Amortized Purchase	Labor
Baseline Equipment		
Small Tools	$0.33/hr	$0.33/hr
Innovative Equipment		
Spectro Xepos Analyzer	$45.90/hr	$70.09/hr
Chemplex Manual Press	$1.60/hr	$1.60/hr
Small Tools	$0.33/hr	$0.33/hr

Note: The operation cost shown above includes amortization of the equipment purchase price and the annual costs for repair/maintenance/calibration (labor for operation during work is not included).

Unit Costs and Fixed Costs

Table 7 shows the unit costs, fixed costs, and production rates for the innovative and baseline technologies. These costs are based on the costs summarized in Appendix B, Table B-1 and B-2.

Table 7. Summary of Unit Costs, Fixed Costs, and Production Rates

COST ELEMENT	BASELINE COST	PRODUCTION RATE	INNOVATIVE COST	PRODUCTION RATE
Mobilization	$160.10 ea mob.	N/A	$160.10 ea mob.	N/A
Characterization	$917.51/sample	8.1 min/sample	$40.19/sample	.45 min/sample
Demobilization	$38.80 ea demob	N/A	$38.80 ea demob	N/A
Disposal	$150.00 /cf	N/A	$150.00 /cf	N/A

Note: The characterization unit costs shown above are based on the averaged costs for donning/doffing PPE, collecting samples, packing and delivering samples, 14 PCB analyses, 14 metals analyses, and validation as shown in Table B-3 of Appendix B.

The baseline costs for characterization include costs for scraping samples, packaging and delivering the samples to the laboratory, laboratory costs, and sample validation (see Appendix B, Table B-3 for the baseline technology costs). The innovative technology incurs costs from scraping samples, putting samples into storage, calibrating the SPECTRO XEPOS Analyzer, preparing the samples, and analyzing the samples (see Appendix B, Table B-2 for the innovative technology costs).

Payback Period

For this demonstration, the innovative technology saves approximately $24,559 per job over the baseline for a job size of 28 samples. At this rate of savings, the purchase price of $63,072 would be recovered by performing approximately three jobs (28 samples each) using the innovative technology. Figure 12 illustrates the breakeven point for recovering the initial expense for the SPECTRO XEPOS Analyzer.

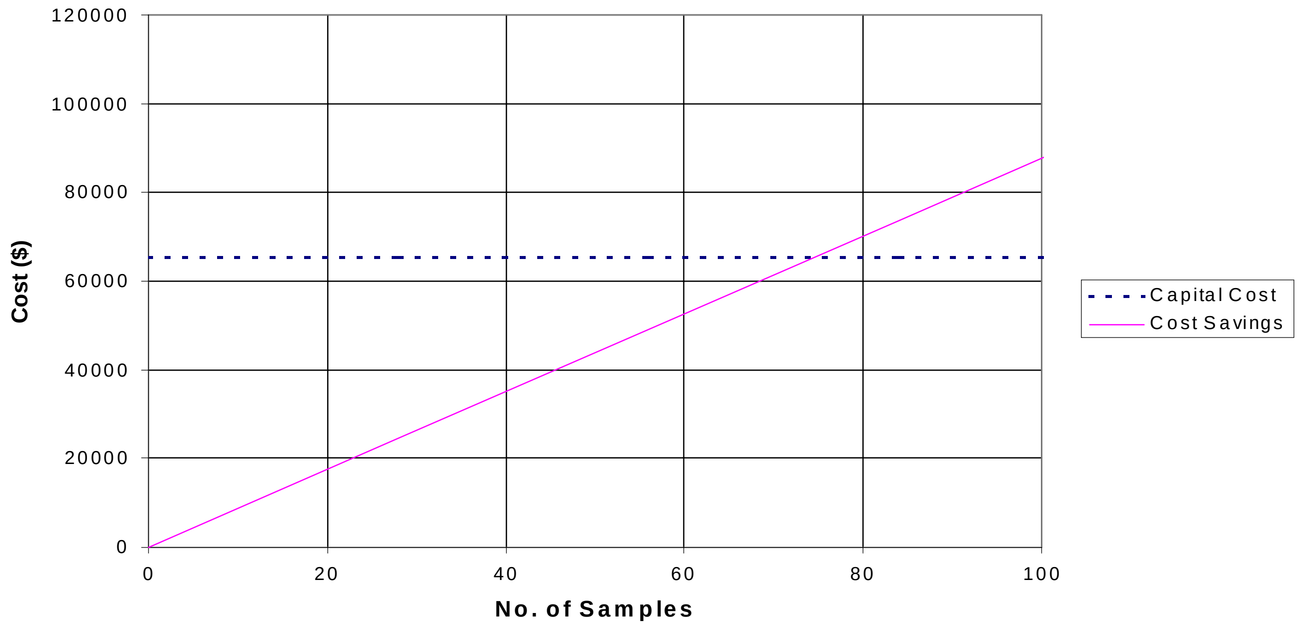

Figure 12. Capital Cost Recovery.

Observed Costs for Demonstration

Figure 13 summarizes the costs observed for the innovative and baseline technology for 28 samples gathered. The details of these costs are shown in Appendix B and includes Tables B-2 and B-3, which can be used to compute site-specific costs by adjusting for different labor rates, crew makeup, lab costs, etc.

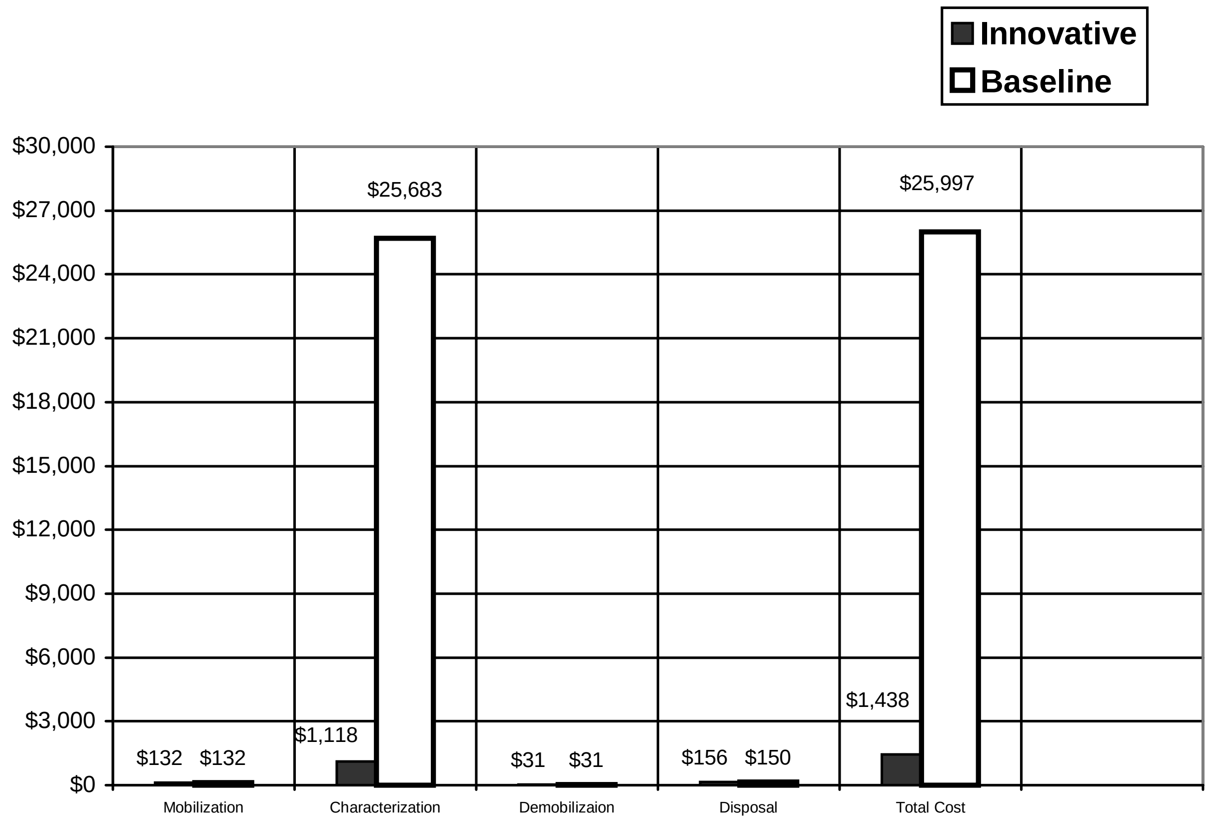

Figure 13. Summary of Technology Costs.

Cost Conclusions

The innovative technology is approximately 6% of the cost of the baseline technology for this demonstration. The savings result from three significant differences:

- The sample size required for the analysis by the SPECTRO XEPOS Analyzer is much less than what is required by the contact laboratory program. The SPECTRO XEPOS Analyzer requires 5 grams of material as opposed to the 90 grams required at the contact laboratory program (CLP). This makes taking the samples much faster for the in-house analyzer.
- Sample laboratory analysis costs apply only to the baseline technology. At approximately $1,320 per metal sample analysis, and $200 per PCB sample analysis, large expenditure is required each time sample analysis is performed. The $1,320 per metal sample analysis and $200 per PCB sample cost is for the laboratory analysis fee and does not include labor for collecting the samples
- Sample validation performed by the Sample Management office at INEEL for the baseline technology requires significant effort compared to the minimal time required for calibrating the SPECTRO XEPOS Analyzer and checking it for reproducibility.

The single most significant difference for this demonstration is the laboratory analysis cost. The scenario used in this demonstration would be typical for field characterization work. Different types of analyses such as field screening or confirmatory sampling may be associated with other situations. Job-specific criteria should be considered when pricing this activity, if required for the type of analysis prescribed. Use of the SPECTRO XEPOS Analyzer eliminated the need for laboratory analysis in this demonstration.

It is also apparent from the other cost differences that a more stringent quality control process is in place for the baseline technology. This defined baseline process includes adding chain of custody requirements, paper work, label preparation, and validation of sample analysis. A more stringent process definition for the innovative technology would make a difference in the overall results. However, in most cases, it is expected the innovative technology will be more cost effective.

The purchase of the Chemplex Manual Press was an optional item for this demonstration. Elimination of this item will result in initial cost savings, conversely, labor costs for preparation of the samples will increase. It is not felt that there would be any cost savings by not purchasing this item, because the press does not require maintenance, and much like many hand tools can last for over 20 years if used properly.

SECTION 6
REGULATORY AND POLICY ISSUES

Regulatory Considerations

There are several issues that must be addressed when purchasing an instrument that uses x-ray. In most states, the instrument must be registered with the state as a radiation-generating device. The instrument must be inspected and surveyed upon arrival to determine if it has been damaged in shipment and to determine the actual radiation levels around the instrument when in use. At the INEEL, the owner must comply with Management Control Procedure (MCP)-138, *Control and Registration of Radiation-Generating Devices*, which outline the responsibility of the owners and operators of the instrument.

According to MCP 138, the operator must have the following training:

- Radiation Worker I or II
- Training specific to the instrument provided by the vendor or custodian of the instrument.

Depending upon the state, the room where the instrument is stored and used may require radiation signs posted on all access doors. A warning light may also be required outside of the room indicating when the X-ray is on. Based on the low levels of radiation produced by the SPECTRO XEPOS at the INEEL, warning lights are not required.

At the INEEL, a written procedure is required that would outline the use and maintenance of the radiation generating device as outlined in MCP-138.

Some states will require that the user wear a dosimeter to measure the dose of radiation that the worker/operator is exposed to. Based on the small amount of radiation produced, the INEEL does not require the operator to wear a dosimeter.

Safety, Risks, Benefits, and Community Reaction

The SPECTRO XEPOS has been well-designed and minimizes safety concerns by ensuring that the x-ray tube is well-shielded to prevent the emission of radiation to the worker. Other safety-related concerns would apply to all laboratory instruments such as maintaining safe laboratory practices and good housekeeping to minimize any concern of exposure to hazardous contaminants associated with sample preparation and handling. The instrument operates using 220 V power source, so electricity may be a safety concern.

The SPECTRO XEPOS can be used to replace a majority of laboratory analysis, specifically when dealing with inorganic analysis such as RCRA metals. For PCBs, the instrument can be used to reduce the number of samples that must be sent to the laboratory for analysis but, because it does not actually detect PCB, laboratory verification is still needed. If, however, the SPECTRO XEPOS does show a chlorine free reading, laboratory verification should not be required to conclude that the sample is free of PCBs.

The benefits of the SPECTRO XEPOS far outweigh any safety concerns about the equipment itself. Samples can be analyzed quickly and accurately to speed up D&D planning and schedules. The use of this instrument or similar ones aids the DOE in quickly responding to environmental issues that may affect the health of the public or environment.

SECTION 7
LESSONS LEARNED

Implementation Considerations

The innovative technology is a mature technology that performed very well during the INEEL demonstration.

The workers found the innovative technology to be very easy to use and provided results within minutes after preparing the samples. The baseline technology can take as long as 90 days to receive results. There are several items that should be considered during the use of the SPECTRO XEPOS. These recommendations are listed below, along with items that have already been addressed by the manufacturer.

- The XRF technology eliminates the sampler/analyzer from having to perform difficult digestions and extraction procedures that require the use of conventional analytical equipment. These digestion procedures required a dedicated technician to perform and generate a secondary waste that must be disposed of.
- The SPECTRO XEPOS has advantages over other XRF instruments by storing internal standards for a variety of matrices within the instrument database. This eliminates the need to develop standards for each matrix and creating standard curves prior to analyzing each set of samples.
- Sample results can be obtained the same day that the samples are collected as opposed to 90 days or longer as is the case with contract laboratories.
- The cost of the equipment is approximately $65,000. The cost of laboratory analysis is approximately $1,000 per sample. Based on this, it would take 65 samples to recover the cost of the equipment, excluding any other considerations of cost.
- The innovative technology requires only 4 grams of sample material per sample. The laboratory may require as much as 150 grams of material per sample. Because of this there is a significant decrease in the amount of sample that must be collected and there for the cost of sampling activities can be reduced.
- Because the time involved in sampling can be reduced, safety for the workers is increased as well since they spend less time in hazardous environments. As low as reasonably achievable (ALARA) dose savings will be achieved.

Technology Limitations and Needs for Future Development

The SPECTRO XEPOS performed well during this demonstration. There were no significant technology limitations. Minor problems are discussed below.

- For best results, it is recommended that paint or coating samples be ground up into a powder prior to analysis.
- A simpler method of exporting the data generated by the SPECTRO XEPOS would aid the user in being able to quickly incorporate data into spreadsheets and documents.

Technology Selection Considerations

Based on the INEEL demonstration, the innovative technology is better suited than the baseline technology for most sampling activities. The innovative technology is easier to use, more cost effective in the long run, and increases the safety of the workers. There are instances where the baseline technology would be preferable:

- Verification of PCB levels in the media of concern.
- Organic contaminant analysis.

Some steps that can be taken in the sampling methodology, to improve the users ability to predict the presence of PCBs in a sample is to use backgound samples from PCB free material. For instance, if soil is being sampled for PCBs, collect some background samples that do not contain PCBs to analyze also. By analyzing the PCB free samples, a baseline concentration for chlorine can be determined. If the suspect samples contain significantly higher levels of total chlorine, it would indicate a strong need for laboratory analysis. If the total chlorine concentration in the area of interest is not significantly different than the baseline total chlorine concentration, it may be assumed that PCBs are not present. A smaller number of laboratory verification samples would need to be tested, thus reducing laboratory costs.

APPENDIX A
REFERENCES

Lockheed Martin Idaho Technologies Company, 9/15/99, Management Control Procedure-138, INEEL.

APPENDIX B
Cost Comparison Details

Basis of Estimated Cost

The activity titles shown in this cost analysis come from observation of the work. In the estimate, the activities are grouped under higher level work titles per the work breakdown structure shown in the ***Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary*** (HTRW RA WBS) (USACE 1996). The HTRW RA WBS, developed by an interagency group, is used in this analysis to provide consistency with the established national standards.

The costs shown in this analysis are computed from observed duration and hourly rates for the crew and equipment. The following assumptions were used in computing the hourly rates:

- The innovative and the baseline equipment are assumed to be owned by the Government.
- The equipment rates for Government ownership are computed by amortizing the purchase price of the equipment, plus a procurement cost of 5.2% of the purchase price, and the annual calibration costs.
- The equipment hourly rates assume a service life of twenty years for the innovative technology equipment. A one-year service life is assumed for the baseline's miscellaneous small tools allowance. An annual usage of 124 hours per year is assumed for the innovative equipment based on discussions with INEEL's test engineer.
- The equipment hourly rates for the Government's ownership are based on general guidance contained in Office of Management and Budget (OMB) Circular No. A-94, ***Cost Effectiveness Analysis***.
- The standard labor rates established by the Idaho National Engineering and Environmental Laboratory (INEEL) are used in this estimate and include salary, fringe, departmental overhead, material handling markups, and facility service center markups.
- The equipment rates and the labor rates do not include the Lockheed Martin general and administrative (G&A) markups. The G&A are omitted from this analysis to facilitate understanding and comparison with costs for the individual site. The G&A rates for each DOE site vary in magnitude and in the way they are applied. Decision makers seeking site-specific costs can apply their site's rates to this analysis without having to first back-out the rates used at the INEEL.

The analysis does not include costs for oversight engineering, quality assurance, administrative costs for the demonstration, or work plan preparation costs.

The analysis assumes a ten-hour workday.

Activity Descriptions

The scope, computation of production rates, and assumptions (if any) for each work activity is described in this section.

Mobilization (WBS 331.01

Transport from Storage: The baseline equipment will be stored in a sample equipment/supplies storage area located in the Central Facilities Area. The time required to transport the equipment to the work area is based on the recorded durations from the data collection forms. The transport for the innovative equipment is the same as for the baseline. The baseline and innovative equipment includes miscellaneous small tools such as a metal basin, wall scrapers, hammers, and sample containers.

Put on PPE Gear: The samplers put on protective clothing and gear to protect them against any harmful exposure while they are taking various samples. The time required for this activity is approximately 10 minutes.

Table B-1 Personal Protective Equipment Cost Summary

Equipment	Cost Each Time Used ($)	No. Used Per Day	Cost Per Day ($)
Tyvex Coveralls	5.00	2 ea	10.00
Rubber Gloves (outer)	1.30	2 pr	2.60
Gloves (inner)	0.14	2 pr	.28
Gloves (liner)	0.29	2 pr	.58
Safety Glasses	1.28	1 ea	1.28
Total			**14.74**

Pre-Job Safety Meeting: The duration for the pre-job safety meeting is based on the judgement and experience of the test engineer. The labor costs for this activity are based upon an assumed crew rather than the actual demonstration participants. All subsequent activities are also based on the assumed crews. The crew members reflect anticipation of actual field performance for the INEEL site.

Characterization (WBS 331.17)

Take Scrape Samples: This activity accounts for the labor and material costs involved in scraping surface areas and removing soil to collect sample substance. It includes moving the sampling tools between sample areas. Material costs for sample jars are $36.00 per dozen. The Daily Field Logs included sampling from four areas ranging in duration from 5 minutes to 120 minutes for the innovative and baseline combined. These sampling variances resulted from differences in material being sampled and the number of samplers involved in the task. The test engineer indicated that during normal sampling operations only two samplers are required. The samples taken at the INTEC building had only one sampler and the samples at the ETR building had three samplers. To adjust the data collected from these activities to represent two samplers, the time durations were normalized as if two samplers had completed the tasks.

Pack/Deliver Samples: This activity applies to the baseline technology. It includes delivering the manually collected samples to a central shop, packaging the samples and shipping. The shipping cost for the samples is $13.17. The time required to travel to the central shop and package the samples is based on the Daily Field Logs.

Sample Analysis: Laboratory costs apply only to the baseline technology. The type of analysis performed for this demonstration was a contact laboratory program (CLP) List of Metals. This would be typical for a field characterization scenario. Different types of analyses may be associated with other scenarios such as field screening or confirmatory sampling. Job specific criteria should be considered when pricing this activity.

Sample Validation: Once the lab analysis comes back from the lab for the baseline technology, the data requires validation. The Sample Management office at INEEL performs validation. The duration of 1 chemist full time for 10 days is based on information received by the test engineer from that office. The duration is a typical requirement for sample validation of organic contaminants.

Containerize Samples: This task for the innovative technology, involves putting the samples gathered at the sample sites into labeled jars for identification.

R&R Samples: The samples gathered from the test sites need to be retrieved and relocated to the area in the Central Facilities Area (CFA) where the sample analysis performed by the Spectro Xepos Analysis was performed. This task for the innovative technology consists of organizing the samples and getting them ready for the preparation phase of the analysis.

Put on PPE Gear: During the innovative analysis, protective clothing must be worn to protect the samplers from any exposure to harmful agents. It takes two samplers approximately 10 minutes to suit up.

Calibrate Equipment: This activity accounts for calibrating adjustments being made to the Spectro Xepos Analyzer. The test engineer indicated that typically the equipment is calibrated once per week. The duration of 5 minutes per calibration is based on discussions with the test engineer.

Prepare Samples for Analysis: The preparation of samples for the innovative technology is a five step process. First, the material is ground into a powder. For this demonstration, this was completed with the aid of a Chemplex grinder/mixer. Second, a binding agent is added to the sample. Next, the material is mixed uniformly. Then, the powder is pressed into small pellets. Finally, the samples are either put into storage, or tested.

Sample Analysis: The innovative analysis of samples takes place on the average of once per week. The pellets are placed on the Xepos Spectro Analyzer which detects the presence of Chloride. This process takes approximately 10 minutes per sample.

Recontainerize the Samples: For the innovative analysis, the samples are put back into the glass jars for preparation to be returned to their waste generator.

Productivity Loss: This activity accounts for real work situations which include work delays or inefficiencies that add to the overall duration of the job and result in added cost. Specific examples of productivity loss elements for this particular demonstration are the following:

- (ETR Delay Tank Sampling) – There were two five minute productivity losses one which occurred between gathering the supplies and the pre-job briefing and one which occurred between the pre-job briefing and putting on the PPE equipment.
- (Security Training Facility) – There was a five minute productivity loss, which occurred between the time the pre-job briefing ended and the time sampling started.
- (INTEC Building) – There was a five minute productivity loss for the relocation of equipment between the upper room and the lower room of the INTEC building.

Demobilization (WBS 331.21)

Prepare for Storage: This activity includes breaking down the equipment, cleaning as needed and stowing it in the equipment cases. The duration is based on the test engineer's judgement.

Transport to Storage: Similar to Transport from Storage.

Remove PPE Gear: Similar to Put on PPE Gear.

Disposal (WBS 331.18)

Dispose of Material: The samples are pulled out of storage to be disposed of in close proximity to where they were originally taken. This process usually occurs in conjunction with other sampling operations to save time.

Cost Estimate Details

The cost analysis details are summarized in Tables B-2 and B-3. The tables break out each member of the crew, each labor rate, each piece of equipment used, each equipment rate, each activity duration and all production rates so that site specific differences in these items can be identified and a site specific cost estimate may be developed.

Table B-2. Innovative Technology Cost Summary

Work Breakdown Structure	Unit	Unit Cost $/unit	Quan-tity	Total Cost	Computation of Unit Cost: Pro-duction Rate	Duration (hr)	Labor Item	$/hr	Equipment Items	$/hr	Other $	Comments
Facility Deactivation, Decommissioning, & Dismantlement								**TOTAL COST FOR DEMONSTRATION =**			**$**	**1,437.89**
Mobilization (WBS 331.01)										Subtotal =	$	132.39
Transport from Storage	ea	21.05	1	$ 21.05		0.271	2SA	77.34	ST on standby	0.33		Bring out Equipment
Pre-Job Safety Meeting	ea	111.34	1	$ 111.34		0.500	2SA + 1JS + 1RT + 1IH + 1LA	222.36	ST on standby	0.33		Discuss sampling
Characterization (WBS 331.17)										Subtotal =	$	1,118.29
Put on PPE Gear	ea	27.71	1	$ 27.71		0.167	2SA	77.34	ST on standby	0.33	14.74	Protective Gear Costs
Take Scrape Samples	ea	3.58	28	$ 100.35	133sample/hr		2SA	77.34	ST	0.33	3.00	Sample Jars @ $36/dozen
Containerize Samples	ea	6.47	1	$ 6.47		0.083	2SA	77.34	ST on standby	0.33		
R&R Samples	ea	6.44	1	$ 6.44		0.083	2SA	77.34		0.00		Place samples in storage
Put on PPE Gear	ea	27.58	1	$ 27.58		0.166	2SA	77.34		0.00	14.74	Prot. gear for sample analysi
Calibrate Equipment	ea	12.24	1	$ 12.24		0.083	2SA	77.34	PCBA	70.09		Calibrate analyzer once / we
Prep Samples for Anal.	ea	7.67	28	$ 214.80	10.29samples/hr		2SA	77.34	MP	1.60		Grinding up samples
Analyze Samples	ea	24.57	28	$ 688.01	6samples/hr		2SA	77.34	PCBA	70.09		
Recontainerize Samples	ea	6.42	1	$ 6.42		0.083	2SA	77.34		0.00		Put in jars for disposal
Remove PPE Gear	ea	8.08	1	$ 8.08		0.104	2SA	77.34	ST on standby	0.33		
Productivity Loss	man day	20.19	1.00	$ 20.19		0.260	2SA	77.34	ST	0.33		Assume 10 hour man day
Demobilization (WBS 331.21)										Subtotal =	$	30.76
Prep Equip. for Storage	ea	11.34	1	$ 11.34		0.146	2SA	77.34	ST on standby	0.33		Wipe down equipment
Transport to Storage	ea	19.42	1	$ 19.42		0.250	2SA	77.34	ST on standby	0.33		
Disposal (WBS 331.18)										Subtotal =	$	156.45
Dispose of Material	ea	6.45	1.00	$ 6.45		0.083	2SA	77.34	ST on standby	0.33		Put samples back at waste
Dispose of PPE	ea	150.00	1.00	$ 150.00							150.00	Dispose of PPE material

Labor and Equipment Rates used to Compute Unit Cost

Crew Item	Rate $/hr	Abbrev-eation	Crew Item	Rate $/hr	Abbreveation	Equipment Item	Rate $/hr	Abbrev-eation	Equipment Item	Rate $/hr	Abbrev-eation
Job Supervisor	51.53	JS				Small Tools	0.33	ST			
Sampler	38.67	SA				PCB analyzer	70.09	PCBA			
Laborer	32.34	LB				Manual Press	1.60	MP			
Radiation Technologist	35.77	RT									
Industrial Hygenist	34.32	IH									

Notes:

1. Unit cost = (labor + equipment rate) X duration + other costs, or = (labor + equipment rate)/production rate + other costs
2. Abbreviations for units: ea = each, hr = hour.
3. Other abbreviations not identified: WBS = Work Breakdown Structure.

Table B-3. Baseline Technology Cost Summary

Work Breakdown Structure	Unit	Unit Cost $/unit	Quan-tity	Total Cost	Computation of Unit Cost: Pro-duction Rate	Duration (hr)	Labor Item	$/hr	Equipment Items	$/hr	Other $	Comments
Facility Deactivation, Decommissioning, & Dismantlement								**TOTAL COST FOR DEMONSTRATION =**			**$**	**25,996.55**
Mobilization (WBS 331.01)										Subtotal =	$	132.39
Transport from Storage	ea	21.05	1	$ 21.05		0.271	2SA	77.34	ST on standby	0.33		
Pre-Job Safety Meeting	ea	111.34	1	$ 111.34		0.500	2SA + 1JS + 1RT + 1IH + 1LA	222.36	ST on standby	0.33		
Characterization (WBS 331.17)										Subtotal =	$	25,683.40
Put on PPE gear	ea	27.71	1	$ 27.71		0.167	2SA	77.34	ST on standby	0.33	14.74	Travel Time
Take Scrape Samples	ea	13.48	28	$ 377.49	7.41samples/hr		2SA	77.34	ST	0.33	3.00	Sample Jars @ $36/dozen
Pack/Deliver Samples	ea	71.42	1	$ 71.42		0.750	2SA	77.34	ST	0.33	13.17	Includes shipping cost
Sample Analysis	ea	199.68	14	$ 2,795.52						0.00	199.68	Laboratory costs for PCB's
Sample Analysis	ea	1,317.93	14	$ 18,451.02							1,317.93	Laboratory costs for Metals
Sample Validation	ea	3,932.00	1	$ 3,932.00		80	1CH	49.15				Assume 8 hour day
Remove PPE Gear	ea	8.04	1	$ 8.04		0.104	2SA	77.34				
Productivity Loss	man day	20.19	1.00	$ 20.19		0.260	2SA	77.34	ST	0.33		Assume 10 hour man day
Demobilization (WBS 331.21)										Subtotal =	$	30.76
Prepare for Storage	ea	11.34	1	$ 11.34		0.146	2SA	77.34	ST on standby	0.33		
Transport to Storage	ea	19.42	1	$ 19.42		0.25	2SA	77.34	ST on standby	0.33		
Disposal (WBS 331.18)										Subtotal =	$	150.00
Dispose of PPE Equipmer	ea	150.00	1.00	$ 150.00							150.00	Dispose of PPE

Labor and Equipment Rates used to Compute Unit Cost

Crew Item	Rate $/hr	Abbrev-eation	Crew Item	Rate $/hr	Abbreveation	Equipment Item	Rate $/hr	Abbrev-eation	Equipment Item	Rate $/hr	Abbrev-eation
Job Supervisor	51.53	JS				Small Tools	0.33	ST			
Sampler	38.67	SA									
Laborer	32.34	LB									
Radiation Technologist	35.77	RT									
Industrial Hygenist	34.32	IH									
Chemist	49.15	CH									

Notes:

1. Unit cost = (labor + equipment rate) X duration + other costs, or = (labor + equipment rate)/production rate + other costs
2. Abbreviations for units: ea = each, hr = hour.
3. Other abbreviations not identified: WBS = Work Breakdown Structure.

APPENDIX C
ACRONYMS AND ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
CF	Central Facility
CLP	Contract Laboratory Program
D&D	Decontamination and Decommissioning
DDFA	Deactivation and Decommissioning Focus Area
DOE	Department of Energy
ETR	Engineering Test Reactor
GC	Gas Chromatograph
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
ITSR	Innovative Technology Summary Report
LSDDP	Large Scale Demonstration and Deployment Project
MCP	Management Control Procedure
OST	Office of Science and Technology
PCB	Polychlorinated Byphenyl
PPE	Personal Protective Equipment
ppmw	Parts per Million by Weight
RCRA	Resource Conservation and Recovery Act
RCT	Radcon Technician
STF	Security Training Facility
TRA	Test Reactor Area
VOC	Volatile Organic Compound
XRF	X-ray Fluorescence